EXTENDED REPORT

Monovision slows juvenile myopia progression unilaterally

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Aim: To evaluate the acceptability, effectivity, and side effects of a monovision spectacle correction designed to reduce accommodation and myopia progression in schoolchildren.

Methods: Dominant eyes of 11 year old children with myopia (-1.00 to -3.00 D mean spherical equivalent) were corrected for distance; fellow eyes were uncorrected or corrected to keep the refractive imbalance $\leqslant 2.00$ D. Myopia progression was followed with cycloplegic autorefraction and A-scan ultrasonography measures of vitreous chamber depth (VCD) for up to 30 months. Dynamic retinoscopy was used to assess accommodation while reading.

Results: All children accommodated to read with the distance corrected (dominant) eye. Thus, the near corrected eye experienced myopic defocus at all levels of accommodation. Myopia progression in the near corrected eyes was significantly slower than in the distance corrected eyes (inter-eye difference = 0.36 D/year (95% CI: 0.54 to 0.19, p = 0.0015, n = 13); difference in VCD elongation = 0.13 mm/year (95% CI: 0.18 to 0.08, p = 0.0003, n = 13)). After refitting with conventional spectacles, the resultant anisometropia returned to baseline levels after 9–18 months.

Conclusions: Monovision is not effective in reducing accommodation in juvenile myopia. However, myopia progression was significantly reduced in the near corrected eye, suggesting that sustained myopic defocus slows axial elongation of the human eye.

A nimals raised wearing lenses which impose hyperopic retinal defocus (plane of focus located behind the retina) develop axial myopia.[1][2] In line with these animal studies it has been suggested[3] that focusing errors associated with prolonged accommodation, in particular lag of accommodation (plane of focus behind the retina), might explain the link between prolonged near work and the development of axial myopia in humans. Attempts to reduce accommodative lag by prescribing progressive addition lenses (PALs) to children in order to reduce myopia progression have had limited success.[4–6] Although PALs may slow progression somewhat, the effect is insufficient to control myopia progression in the clinical situation.[6][7] Whether results from animal models are directly applicable to naturally occurring myopia in humans is questionable.[8] A study of undercorrection of myopia[9] found that myopia progressed significantly more rapidly in children who were undercorrected compared to those wearing a full correction, implying that myopic defocus in humans increases the rate of myopia progression. However, in animals myopic defocus slows elongation of the eye and causes hyperopia.[1][2] Animal studies also predict that overcorrection of myopia might accelerate myopia progression in children. However, attempts to manage exotropia,[10] or to slow myopia progression with overcorrection,[11] do not appear to increase myopia progression.

Alternative theories[12] linking near work and myopia development have proposed that intraocular forces associated with sustained accommodation might lead to eye enlargement, perhaps by "stretching" the sclera. The human eye elongates slightly during accommodation,[13][14] suggesting that prolonged accommodation might lead to a permanent increase in eye length and myopia. On this basis, reducing accommodative effort might act to reduce myopia progression.

A prescription that is widely used to provide a near addition for presbyopic contact lens wearers is monovision, in which one eye is corrected for distance vision while the other is corrected for near vision. In principle, a monovision correction prescribed to children with myopia could reduce accommodative effort during near work and potentially slow myopia progression. Although some aspects of visual function may be compromised with monovision,[15][16] most presbyopic monovision wearers perceive a clear image of the world at distance and at near and are unaware of the anisometropic blur.[17]

The aims of this study were to determine whether children could successfully wear a monovision spectacle correction and whether it would reduce accommodative effort at near. A further aim was to investigate possible side effects of monovision wear, particularly whether it might induce some anisometropia over time. Monovision was prescribed as spectacles rather than contact lenses because the procedure was aimed at 11 year old children for whom spectacles are more universally applicable.

METHODS

Participants were 18 children (11 female, seven male, mean age 11.6 years) with a variety of ethnic origins (10 east Asian, the remainder included white, south Asian (Indian), and Maori/Pasifica). Inclusion criteria were (i) 10–13 years of age, (ii) no previous spectacle or contact lens wear, (iii) both eyes having subjectively determined best sphere refractions between -1.00 D to -3.00 D with astigmatism $\leqslant -1.00$ DC and initial anisometropia $\leqslant 1.00$ D, (iv) both eyes correctable to 6/6 Snellen acuity, and (v) no binocular vision abnormality or ocular pathology. Stereopsis was assessed using the Wirt circles of the Stereotest (Stereo Optical Inc, Chicago, IL, USA). Eye dominance was determined using a simple sighting test.[18]

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Abbreviations: ACD, anterior chamber depth; AXL, axial length; LT, lens thickness; PALs, progressive addition lenses; REML, restricted maximum likelihood; SER, spherical equivalent refraction; VCD, vitreous chamber depth

The study conformed to the tenets of the Declaration of Helsinki and was approved by the University of Auckland human subjects ethics committee. Informed consent in writing from parents and assent from children were obtained following written explanations and verbal discussion of the nature of the study and possible risks and benefits. Participants were free to withdraw at any time, but any suggestion that performance at school was compromised or any reduction in best corrected acuity in either eye, or the development of more than 1.00 D of anisometropia compared to baseline, resulted in automatic participant withdrawal. A maximum duration for monovision wear of 2½ years was specified, comparable with other studies.[9] Data were periodically analysed and once a statistically significant result that fulfilled the aims had been obtained, the study was terminated. Termination accounts for the variable duration of monovision wear (8–30 months) among participants. All participants were then prescribed conventional spectacles and their refractive error measured 9–18 months later.

The dominant eyes of all children were corrected for distance because this is the most common procedure in monovision contact lens practice.[17] The non-dominant eyes viewed through a plano lens unless the resultant refractive imbalance between the eyes exceeded 2.00 D, when the non-dominant eye was partially corrected to keep the imbalance equal to 2.00 D. As myopia progressed, the dominant eye was corrected to maintain 6/6 acuity while keeping the refractive imbalance no greater than 2.00 D. Participants were advised to build up to full time wear as quickly as possible. Spectacle wear was either full time (8 hours/day or more) or part-time.

Spherical equivalent refraction (SER), measured by cycloplegic autorefraction and vitreous chamber depth (VCD), measured by A-scan ultrasonography, were used to monitor myopia progression. Cycloplegia was induced with 1% tropicamide (two drops/eye, 5 minutes apart) after corneal anaesthesia with benoxinate: measures were made 30 minutes later. This protocol produces effective cycloplegia in children of this age.[19][20] A portable autorefractor (Retinomax K-plus, Nikon Inc, Tokyo, Japan) was used to obtain two measures for each eye. Each measure was expressed in power vector form,[21] with M representing the spherical component and J_0 and J_{45} the powers of the equivalent Jackson cross cylinders at axes 0° and 45°. The average M component was used as the measure of SER. Ocular component dimensions (anterior chamber depth, ACD, lens thickness LT, and axial length, AXL) were measured by A-scan ultrasonography (Ophthasonic a-scan/b-scan III, Teknar Inc, St Louis, MO, USA). Vitreous chamber depth was computed as VCD = AXL − (ACD + LT) averaged form three measures for each eye. Measures were made on the day spectacles were dispensed (baseline) and at follow up visits approximately 8 months apart for an average period of 18.7 months (range 8–30 months). The same investigator (author) made all outcome measures and was not masked to participant data.

The accommodative status of the eyes when reading with the monovision prescription was determined by Cross-Nott dynamic streak retinoscopy.[22] In this method, the working distance is varied in order to find the neutral retinoscopy reflex in each eye. At neutral, the plane of the retinoscope sight hole coincides with the point in space conjugate with the retina.

Linear mixed effects models were used to investigate the development of inter-eye differences over time. The model took account of the paired eyes, the repeated measures taken on the same eye and, importantly, the different number of measurements made per subject. The models were fit in SAS (SAS Institute Inc, USA) using the procedure PROC MIXED[23] and the restricted maximum likelihood (REML) fitting algorithm.

Table 1 Participant data showing sex, sighting dominance, duration of monovision wear (months), and wear pattern as full time (FT) or part-time (PT)

No	Sex	Dominant eye	Duration (months)	Dominant eye (distance corrected)					Non-dominant eye (near corrected)					Anisometropia (SER(dist) − SER(near)) (D)		
				VCD(dist) (mm)		SER(dist) (D)			VCD(near) (mm)		SER(near) (D)					
				Baseline	After MV	Baseline	After MV	Final	Baseline	After MV	Baseline	After MV	Final	Baseline	After MV	Final
1	F	RE	30 (PT)	17.47	18.33	−1.50	−3.38	−3.13	17.45	18.01	−1.56	−3.13	−3.13	0.06	0.25	0.00
2	F	RE	29 (FT)	16.52	17.12	−1.69	−3.56	−3.88	16.52	17.10	−2.31	−3.94	−4.00	0.62	0.38	0.12
3	M	RE	28 (FT)	16.95	17.37	−1.38	−3.00	−3.75	16.98	17.23	−1.25	−2.13	−3.50	0.13	0.87	0.25
4	M	LE	26 (FT)	17.19	18.07	−1.56	−3.81	−4.48	17.20	17.73	−1.81	−2.56	−4.00	0.25	1.25	0.38
5	F	LE	23 (PT)	15.98	16.60	−0.61	−1.38	−2.25	16.04	16.53	−0.86	−1.63	−2.38	0.25	0.25	0.13
6	F	RE	18 (PT)	16.66	17.05	−3.19	−4.25	−4.63	16.60	17.00	−3.19	−4.06	−4.33	0.00	0.19	0.30
7	F	RE	16 (FT)	18.42	18.64	−2.25	−3.38	−3.25	18.35	18.40	−2.38	−2.56	−2.75	0.13	0.82	0.50
8	M	LE	16 (FT)	17.31	17.57	−1.56	−2.13	−2.00	17.39	17.29	−1.81	−1.44	−1.50	0.25	0.69	0.50
9	M	RE	15 (FT)	17.54	17.99	−1.75	−2.56	−2.75	17.46	17.81	−1.44	−2.00	−2.75	0.31	0.56	0.00
10	F	RE	13 (FT)	16.90	17.35	−1.70	−3.10	−3.00	16.88	16.99	−1.13	−1.18	−1.75	0.57	1.92	0.25
11	F	RE	12 (FT)	16.22	16.35	−1.13	−1.19	−2.00	16.07	16.03	−1.25	−1.13	−1.75	0.12	0.06	0.25
12	F	LE	9 (FT)	17.22	17.58	−1.64	−2.44	−3.00	17.30	17.48	−2.13	−2.38	−2.63	0.49	0.06	0.37
13	M	RE	8 (PT)	16.93	17.07	−1.00	−1.44	−1.83	16.96	16.99	−0.88	−1.31	−1.75	0.12	0.13	0.08
		mean	18.7	17.02	17.47	−1.61	−2.74	−3.07	17.02	17.28	−1.69	−2.27	−2.86	0.25	0.57	0.24
		SD	7.9	0.63	0.66	0.62	0.98	0.91	0.63	0.63	0.67	0.98	0.91	0.20	0.54	0.17

Biometric data for each eye of each participant shows vitreous chamber depths (VCD) at baseline and following monovision wear (after MV) and spherical equivalent refractive error (cycloplegic SER) at baseline, following monovision wear (after MV) and following 9–18 months of conventional spectacle wear (Final, non-cycloplegic). Anisometropia (right columns) is absolute value in each case.
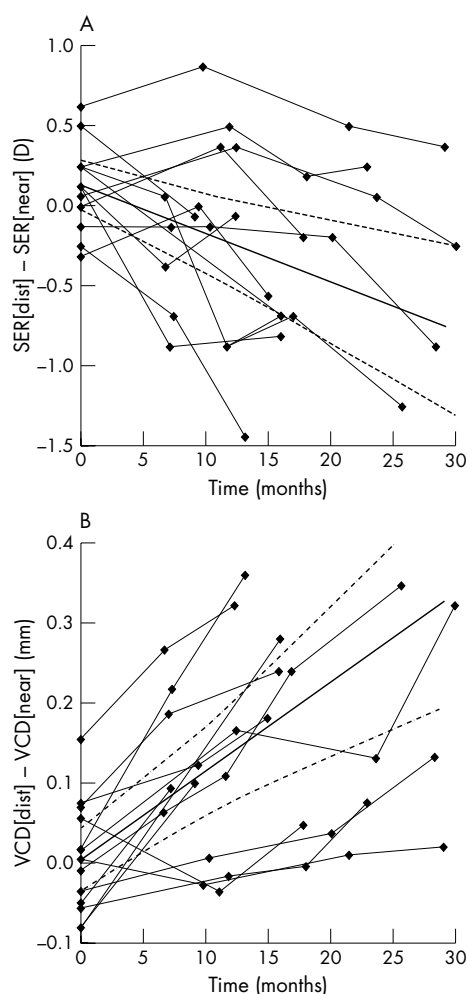
Figure 1 (A) Development of the difference in refractive error between distance and near corrected eyes (SER(dist) − SER(near)) for each of the 13 participants: the thick line shows the mixed effects model estimate of the average trajectory, with 95% confidence intervals (broken line). The negative slope (−0.36 D/year) indicates that myopia progressed more slowly in the near corrected eyes. (B) Development of the difference in vitreous chamber depth between the distance and the near corrected eyes (VCD(dist) − VCD(near)) for each of the 13 participants: the thick line shows the mixed effects model estimate of the average trajectory, with 95% confidence intervals (broken line). The positive slope (0.13 mm/year) indicates that the vitreous chamber elongated more slowly in the near corrected eyes.

RESULTS
Monovision spectacle wear
Table 1 shows participants' eye dominance, sex, wear time, and measures of VCD and SER at baseline, after monovision wear, and following conventional spectacle wear. Not shown are details of children who dropped out of the study before the first follow up visit: two did not wish to continue with the cycloplegic measures, two moved abroad, and one could not be contacted. In table 1, two children (nos 6 and 7) were prescribed conventional spectacles after 18 months and 16 months because they were unhappy with their vision with monovision. Two children (nos 4 and 10) were prescribed conventional spectacles after 26 months and 13 months, respectively, because they developed more than 1.00 D of anisometropia relative to baseline. After several months of adaptation to monovision, dynamic retinoscopy (see Methods) showed that all children accommodated to read with the distance corrected (dominant) eye rather than with the near corrected eye. Consequently, the near corrected

eyes experienced myopic defocus at all levels of accommodation. Stereoacuity, which was 40 seconds of arc before recruitment, was typically reduced to between 40 seconds of arc and 80 seconds of arc with monovision, but returned to 40 seconds of arc with a conventional correction. Best corrected acuity remained at baseline levels (typically 6/5) in all eyes.

Refractive error versus time
The baseline SERs (table 1) of distance corrected eyes (−1.61 (0.62) D (mean (SD)) and near corrected eyes (−1.69 (0.67) D) were not different (p = 0.383). Myopia progression during monovision wear, computed as (SER(afterMV) − SER(baseline)) × 12/(months of wear), gave a mean progression rate across participants of −0.72 (0.32) D/year in distance corrected eyes and −0.32 (0.30) D/year in near corrected eyes. Figure 1A shows how the inter-eye difference in refraction (SER(dist) − SER(near)) developed over time for each of the participants and also the mixed model estimate of the average population trajectory with 95% confidence intervals. The model estimated the average
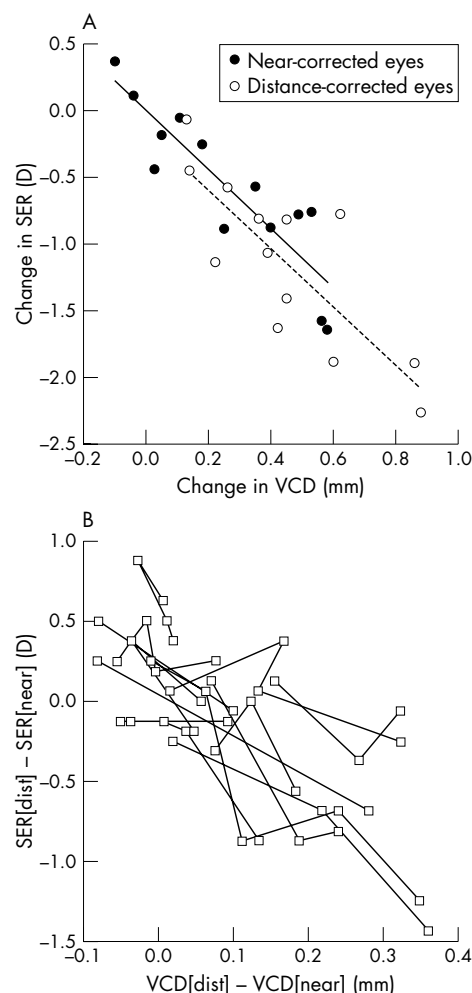

Figure 2 (A) Change in refractive error versus change in vitreous chamber depth (VCD) for distance corrected eyes (open symbols) and near corrected eyes (solid symbols) from baseline to end of monovision wear, for 13 participants. The slope of the linear regression for distance corrected eye data (broken line) = −2.16 D/mm (R = 0.81): that for the near corrected eyes (solid line) = −2.22 D/mm (R = 0.88). (B) The relation between difference in SER and difference in VCD at each follow up visit: lines join data for individual participants. The slope of the linear regression (not shown) equalled −2.98 D/mm (R = 0.72).

difference in myopia progression between the eyes as 0.36 D/year (95% CI: 0.54 to 0.19, p = 0.0015, n = 13) with near corrected eyes progressing more slowly than distance corrected eyes. Similar analyses showed that no inter-eye differences developed for either J_0 (p = 0.14) or J_{45} (p = 0.15). Analysis of the effect of part-time versus full time wear of monovision suggested that the difference in progression rate (D/year) between the two eyes was less in part-time wearers (p = 0.04), but the difference in VCD elongation rate between the two eyes was not different for part-time and full time wear (p = 0.11). Columns labelled ''Final'' in table 1 show non-cycloplegic subjective refractions for each eye after 9–18 months of conventional spectacle wear following the study period. Although significant levels of anisometropia (table 1) developed during monovision wear in some participants, final anisometropia (range 0.00 to 0.50 D) returned to equal baseline levels (p = 0.43) following conventional spectacle wear. Although these final measures were non-cycloplegic refractions, the data suggest that during conventional spectacle wear the loss of induced anisometropia was accounted for by a higher progression rate in the previously near corrected eyes (approximately 0.66 (0.51) D/year) than in the distance corrected eyes (approximately 0.46 (0.35) D/year) although these rates were not significantly different (p = 0.10).

Changes in ocular dimensions with time

The mean baseline VCDs of the distance and near corrected eyes were equal (17.02 (0.63) mm) with ranges of 15.98–18.42 mm and 16.04–18.35 mm respectively (table 1). Figure 1B shows the development of inter-eye difference in VCD between the distance and near corrected eyes (VCD(dist) − VCD(near)) over time for each of the participants. The mixed model analysis showed the mean difference in vitreous chamber elongation rate equalled 0.13 mm/year (95% CI: 0.18 to 0.08, p = 0.0003, n = 13), with the near corrected eyes elongating more slowly than the distance corrected eyes. Similar analyses showed that axial length increased more slowly in near corrected eyes than in distance corrected eyes (mean difference 0.10 mm/year (95% CI: 0.19 to 0.02, p = 0.016, n = 13) but no inter-eye differences developed for lens thickness (p = 0.253), anterior chamber depth (p = 0.509), or corneal radius (p = 0.451).

Correlation between changes in refractive error and vitreous chamber depth

Figure 2A shows the linear regression relations between the change in SER during monovision wear (SER(afterMV) − SER(baseline)) and the change in VCD (VCD(afterMV) − VCD(baseline)) for all eyes. With refractive error as the dependent variable, the slopes of the relations were similar (−2.16 D/mm, R = 0.81, for distance corrected eyes and −2.22 D/mm, R = 0.88, for near corrected eyes). Thus, although the progression rates were different in the two eyes, both rates correlated closely with increases in VCD. Figure 2B illustrates the relation between the difference in refractive error (SER(dist) − SER(near)) and the difference in VCD between the distance and near corrected eyes (VCD(dist) − VCD(near)) at each visit for each participant. The slope of the relation obtained by linear regression (not shown) equalled −2.98 D/mm (R = 0.72).

DISCUSSION

The primary reason for investigating a monovision prescription was its potential to reduce accommodation. Unexpectedly, children accommodated to read with the distance corrected eye, so accommodation was not appreciably reduced by monovision. A possible explanation for this finding is that the accommodation response followed accommodation demand in the dominant eye, as reported for perceptually rivalrous stimuli.[24] Another explanation (suggested by unpublished data from this laboratory) may be that accommodation was driven by the convergence necessary to maintain fusion while reading. Whatever the explanation, the result highlights the fact that undercorrecting one eye has quite different optical consequences than bilateral undercorrection. Bilateral undercorrection results in myopic defocus at distance but clear retinal images at near in both eyes. In contrast, unilateral undercorrection of the non-dominant eye results in continuous myopic defocus in the undercorrected eye at both distance and near. As expected,[25] stereoacuity was reduced in some children with monovision but returned to 40 seconds of arc in all children with a balanced prescription. The best corrected acuity of all eyes remained at baseline levels (typically 6/5) throughout the study and based on these clinical tests there was no evidence of any change in visual function following monovision wear.

A significant finding was that the rate of myopia progression was slower in the near corrected eyes than in the distance corrected eyes. While participant dropout is of some concern, the demonstrated effect in 13 participants suggests that it can be generalised to at least 75% of the equivalent myopic population (p = 0.05).[26] Although it is probable that the difference in progression rates can be attributed to a slowing of progression in the near corrected eyes because of sustained myopic defocus, the possibility of some increase in progression rate in the distance corrected eyes cannot be ruled out. Progression is typically most rapid during the initial stages of myopia development and slows to a stable refraction over a number of years.[27] Accordingly, Grice et al[28] reported a mean progression rate in the first year after myopia onset of −0.87 D/year in a group of 19 children, whereas children with longer standing myopia (for example, those wearing single vision lenses as controls in PAL studies) typically have progression rates between 0.5–0.7 D/year.[4–6 29] Therefore, while the progression rate in distance corrected eyes of −0.72 D/year found in the present study is to be expected, that of −0.32 D/year in near corrected eyes is lower than expected for children who had only recently developed myopia and were receiving their first optical correction.

For all eyes myopia progression was closely correlated with changes in VCD. The slopes of the relations were comparable to the theoretical value of −2.70 D/mm[30] suggesting that most of the difference in progression rate between the eyes could be accounted for by the difference in their vitreous chamber elongation rates.

In conclusion, monovision is not effective in reducing accommodation in juvenile myopia. However, the results suggest that myopic retinal defocus acts as an anti-myopiagenic stimulus that counters abnormal axial elongation of the human eye. This conclusion is the opposite of that reached after bilateral undercorrection of children with myopia[9] but it is consistent with the results of animal studies.[1 2 31]

REFERENCES

1 **Schaeffel F**, Glasser A, Howland HC. Accommodation, refractive error and eye growth in chickens. *Vis Res* 1988;**28**:639–57.
2 **Hung LF**, Crawford ML, Smith EL. Spectacle lenses alter eye growth and the refractive status of young monkeys. *Nat Med* 1995;**1**:761–5.
3 **Gwiazda J**, Thorn F, Bauer J, *et al.* Myopic children show insufficient accommodative response to blur. *Invest Ophthalmol Vis Sci* 1993;**34**:690–4.
4 **Leung JT**, Brown B. Progression of myopia in Hong Kong Chinese schoolchildren is slowed by wearing progressive lenses. *Optom Vis Sci* 1999;**76**:346–54.
5 **Edwards MH**, Li RW, Lam CS, *et al.* The Hong Kong progressive lens myopia control study: study design and main findings. *Invest Ophthalmol Vis Sci* 2002;**43**:2852–8.
6 **Gwiazda J**, Hyman L, Hussein M, *et al.* A randomized clinical trial of progressive addition lenses versus single vision lenses on the progression of myopia in children. *Invest Ophthalmol Vis Sci* 2003;**44**:1492–500.
7 **Saw SM**, Shih-Yen EC, Koh A, *et al.* Interventions to retard myopia progression in children: an evidence-based update. *Ophthalmology* 2002;**109**:415–21.
8 **Zadnik K**, Mutti DO. How applicable are animal myopia models to human juvenile onset myopia? *Vis Res* 1995;**35**:1283–8.
9 **Chung K**, Mohidin N, O'Leary DJ. Undercorrection of myopia enhances rather than inhibits myopia progression. *Vis Res* 2002;**42**:2555–9.
10 **Rutstein RP**, Marsh-Tootle W, London R. Changes in refractive error for exotropes treated with overminus lenses. *Optom Vis Sci* 1989;**66**:487–91.
11 **Goss DA**. Overcorrection as a means of slowing myopic progression. *Am J Optom Physiol Opt* 1984;**61**:85–93.
12 **Young FA**, Leary GA. Accommodation and vitreous chamber pressure: a proposed mechanism for myopia. In: Grosvenor TG, Flom MC, eds. *Refractive anomalies: research and clinical applications.* Boston: Butterworth-Heinemann, 1991:301–9.
13 **Drexler W**, Findl O, Schmetterer L, *et al.* Eye elongation during accommodation in humans: differences between emmetropes and myopes. *Invest Ophthalmol Vis Sci* 1998;**39**:2140–7.
14 **Shum PJ**, Ko LS, Ng CL, *et al.* A biometric study of ocular changes during accommodation. *Am J Ophthalmol* 1993;**115**:76–81.
15 **Back A**, Grant T, Hine N. Comparative visual performance of three presbyopic contact lens corrections. *Optom Vis Sci* 1992;**69**:474–80.
16 **Pardhan S**, Gilchrist J. The effect of monocular defocus on binocular contrast sensitivity. *Ophthalmic Physiol Opt* 1990;**10**:33–6.
17 **Johannsdottir KR**, Stelmach LB. Monovision: a review of the scientific literature. *Optom Vis Sci* 2001;**78**:646–51.
18 **Coren S**, Kaplan CP. Patterns of ocular dominance. *Am J Optom Arch Am Acad Optom* 1973;**50**:283–92.
19 **Owens H**, Garner LF, Yap M, *et al.* Age dependence of ocular biometric measurements under cycloplegia with tropicamide and cyclopentolate. *Clin Exp Optom* 1998;**81**:159–62.
20 **Manny RE**, Hussein M, Scheiman M, *et al.* Tropicamide (1%): an effective cycloplegic agent for myopic children. *Invest Ophthalmol Vis Sci* 2001;**42**:1728–35.
21 **Thibos LN**, Wheeler W, Horner D. Power vectors: an application of Fourier analysis to the description and statistical analysis of refractive error. *Optom Vis Sci* 1997;**74**:367–75.
22 **Rosenfield M**, Portello JK, Blustein GH, *et al.* Comparison of clinical techniques to assess the near accommodative response. *Optom Vis Sci* 1996;**73**:382–8.
23 **Littell RC**, Milliken GA, Stroup WW, *et al.* SAS system for mixed models. Cary, NC: SAS Intstitute Inc, 1996.
24 **Flitcroft DI**, Morley JW. Accommodation in binocular contour rivalry. *Vis Res* 1997;**37**:121–5.
25 **Oguz H**, Oguz V. The effects of experimentally induced anisometropia on stereopsis. *J Pediatr Ophthalmol Strabismus* 2000;**37**:214–18.
26 **Anderson AJ**, Vingrys AJ. Small samples: does size matter? *Invest Ophthalmol Vis Sci* 2001;**42**:1411–13.
27 **Thorn F**, Held R, Gwiazda J. The dynamics of myopia progression onset and offset revealed by exponential growth functions fit to individual longitudinal refractive data. *Invest Ophthalmol Vis Sci* 2002;**43**:E abstract 2866.
28 **Grice K**, Thorn F, McLellan J, *et al.* Myopia progression in children is best described by an exponential growth function. *Invest Ophthalmol Vis Sci* 1998;**39**:S279.
29 **Fulk GW**, Cyert LA, Parker DE. A randomized trial of the effect of single-vision vs bifocal lenses on myopia progression in children with esophoria. *Optom Vis Sci* 2000;**77**:395–401.
30 **Bennett AG**, Rabbetts RB. Distribution and ocular dioptrics of ametropia. *Clinical visual optics*, 2nd ed. Oxford: Butterworth Heinemann, 1989:485–501.
31 **Zhu X**, Winawer JA, Wallman J. Potency of myopic defocus in spectacle lens compensation. *Invest Ophthalmol Vis Sci* 2003;**44**:2818–27.